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ASSESSMENT OF SNOW CRAB IN THE SOUTHERN GULF OF ST. LAWRENCE (AREAS 12, 19, 12E AND 12F) AND ADVICE FOR THE 2014 FISHERY

Figure 1: Map of the southern Gulf of St. Lawrence showing the Crab Fishing Areas (CFAs), fishing grounds and management buffer zones (shaded area). Fishing grounds are labeled as follows: 1 Chaleur Bay, 2 Shediac Valley, 3 Orphan Bank, 4 Bradelle Bank, 5 Magdalen Channel, 6 Cape Breton Corridor, 7 Laurentian Channel, and 8 American Bank.

Context:

Snow crab, Chionoecetes opilio, has been commercially exploited in the southern Gulf of St. Lawrence since the mid-1960s. There are four individually managed fishing areas among which Area 12 (Figure 1) is the largest fishery in terms of its fishable surface, number of participants and landings. In Areas 12, 12E and 12F, the fishing season generally starts in April-May as soon as the Gulf is clear of ice and continues into early summer while in Area 19, the fishery opens after June 30 and usually ends in mid-September. The landing of females is prohibited and only hard-shelled males ≥ 95 mm of carapace width are commercially exploited.

DFO Gulf Region Fisheries and Aquaculture Management requested an assessment of the resource status in 2013 and catch advice for the 2014 fishery. This document provides an overview of the assessment results and the science advice. Catch rates and other fishery performance indicators are reported. The assessment of the status of the southern Gulf snow crab resource (Areas 12, 19, 12E and 12F) is based on fishery independent trawl surveys that provide indicators of: abundance (commercial biomass), reproductive potential (abundance of mature females), and recruitment. A science peer review meeting was conducted January 29-31, 2014 in Moncton, NB. Participants at the science review were from DFO Science, DFO Fisheries Management, fishing industry, Aboriginal organizations, provincial governments, and invited external experts.

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SUMMARY

- Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.
- The landings of snow crab from the southern Gulf of St. Lawrence in 2013 were 26,049 t from a quota of 25,949 t.
- The exploitation rate of the 2013 fishery in the southern Gulf of St. Lawrence was 34.7%.
- The 2013 post-fishery survey biomass of commercial-sized adult male crabs was estimated at 65,868 t (95% confidence interval (C. I.) 56,283 to 76,610 t), a decrease of 12.2% from 2012. The available biomass for the 2014 fishery, derived from the 2013 survey, is within the healthy zone of the Precautionary Approach framework.
- Fifty nine percent (59%) of the 2013 survey biomass, available for the 2014 fishery, is composed of new recruitment (38,981 t). The recruitment to the commercial biomass from the 2013 survey decreased by 20.4% relative to the previous year.
- The residual biomass (26,886 t) from the 2013 survey is comparable to 2012.
- The predicted recruitment of commercial-sized adult male crab for the 2015 fishery was estimated at 37,893 t (95% C.I. 28,568 to 49,114 t).
- A risk analysis of catch options relative to reference points for the 2014 fishery and expected biomass post-fishery is provided.

Fishery performance in 2013 in Area 12:

- The 2013 landings in Area 12 were 22,645 t (quota of 22,548 t).
- The CPUE (expressed as kg per trap haul (kg/th)) in 2013 (76.4 kg/th) increased compared to 2012 (68.0 kg/th).
- The incidence of soft-shelled crab remained low at 2.8%, a decrease compared to 2012 (3.7%).

Fishery performance in 2013 in Area 19:

- The 2013 landings in Area 19 were 2,657 t (quota of 2,654 t).
- The CPUE in 2013 (148.5 kg/th) decreased compared to 2012 (178.1 kg/th).
- The incidence of white-crab decreased from 4.5% in 2012 to 3.0% in 2013.

Fishery performance in 2013 in Area 12E:

- In Area 12E, the landings were 204 t (quota of 204 t).
- The CPUE in 2013 (40.1 kg/th) increased compared to 2012 (32.9 kg/th).
- The incidence of soft-shelled crab in 2013 increased to 15.9%, compared to 3.3% in 2012.

Fishery performance in 2013 in Area 12F:

- The 2012 landings in Area 12F were 543 t (quota of 543 t).
- The CPUE in 2013 (49.0 kg/th) increased compared to 2012 (41.8 kg/th).
- The incidence of soft-shelled crab decreased from 9.4% in 2012 to 2.4% in 2013.

BACKGROUND

Species Biology

Snow crab (*Chionoecetes opilio*) is a crustacean like lobster and shrimp, with a flat, almost circular, body and five pairs of spider-like legs. The hard outer shell is periodically shed in a process called molting. After molting, crabs have a soft shell for a period of 8 to 10 months. Soft-shelled crab is defined by shell hardness (<68 durometer units) and includes both new-soft (condition 1) and clean hard-shelled crab (condition 2). The term white-crab is used in the summer fishery of Area 19 because the newly-molted crabs have reached a relatively harder carapace than those observed during the spring fishery (Areas 12, 12E and 12F). White crab is defined by shell hardness <78 durometer units and includes both new soft (condition 1) and clean hard-shelled crab (condition 2).

Unlike lobsters, snow crabs do not continue to molt throughout their lives. Females stop growing when they acquire a wide abdomen for carrying eggs, which occurs at carapace widths (CW) less than 95mm. Males stop growing when they acquire large claws on the first pair of legs, which can occur at CWs between 40 and 150 mm. Females produce eggs that are carried beneath the abdomen for approximately two years in the southern Gulf of St. Lawrence. The eggs hatch in late spring or early summer and the newly-hatched crab larvae spend 12-15 weeks in the water column. At the end of this period, they settle on the bottom. It takes at least 8-9 years (post-settlement) for males to reach legal commercial size.

Fishery

Until 1994, the snow crab fishery in Area 12 (Figure 1) involved 130 mid-shore crab harvesters from New Brunswick, Québec and Nova Scotia. Since 1997, the PEI coastal fishery, (formerly Areas 25/26) has been integrated into Area 12. In 2003, a portion of the coastal fishery off Cape Breton (formerly Area 18) was also integrated into Area 12. For the purpose of this assessment, Area 12 refers to the management unit that includes snow crab fishing zones 12, 18, 25, and 26 (as defined in regulation) (Figure 1). The number of allocation shares in Area 12 was 264 in 2013.

In 1978, Area 19 (Figure 1) was established for the exclusive use of Cape Breton inshore fish harvesters with vessels less than 13.7 m (45 feet) in length. There were 156 allocation shares in Area 19 in 2013.

Areas 12E and 12F were introduced in 1995 as exploratory fisheries. In 2002, the status of Areas 12E and 12F was changed from exploratory to commercial fishing areas. There were four snow crab allocation shares in Area 12E (from New Brunswick, PEI and Québec) and sixteen snow crab allocation shares in Area 12F (from Nova Scotia and Québec) in 2013.

The minimum legal carapace width for males is 95 mm, females are not harvested and soft-shell and white crab is not targeted by the fishery. Baited traps, constructed of wire or tubular steel, are used to catch crab, mainly on mud or sand-mud bottoms at temperatures ranging from -1 to 4.5°C, and depths ranging from 50 to 280m. The fishery takes place from spring to early summer in Areas 12, 12E and 12F and after June 30 in Area 19.

Management of these fisheries is based on quotas and effort controls (trap allocations, trap dimensions, and seasons). There are at-sea soft-shelled and white crab catch monitoring protocols which allow for closure of portions of each fishing area when the proportion of the catch of males of these carapace conditions exceeds 20%. The protocols are in place to maximize the yield and the reproductive potential of the resource.

Table 1. Number of allocation shares, vessels, traps, quotas, opening dates, and dates of last landing of the snow crab fishery by management area in the southern Gulf of St. Lawrence in 2013.

Characteristic	Area 12	Area 12E	Area 12F	Area 19	Southern Gulf
Allocation shares	264[1]	4	16	156	440
Number of active vessels	299	4	16	99	418
Total number of traps allowed	38,363	450	1,290	1,699	41,802
Opening date	April 28	April 28	April 24	July 15	
Date of last landing	July 15	July 09	June 26	August 21	
Quota (t)	22,548	204	543	2,654	25,949[2]
Landings (t)	22,645	204	543	2,657	26,049

[1] The number of quota allocations among which the Total Allowable Catch is divided (Source: DFO Administrative List for Snow Crab areas 12, 12E, 12F, and 19)

[2] Quota includes 376 t set aside to finance the trawl survey in 2013 (under Section 10 of the Fisheries Act)

The landings from the southern Gulf of St. Lawrence increased from 1969 to the present with three periods of high landings: 1981-1986, 1994-1995, and more recently 2002 to 2009 (Figure 2). The peak landing of the entire history was in 2005 at 36,118 t. The landings of snow crab from the southern Gulf of St. Lawrence in 2013 were 26,049 t from a quota of 25,949 t.

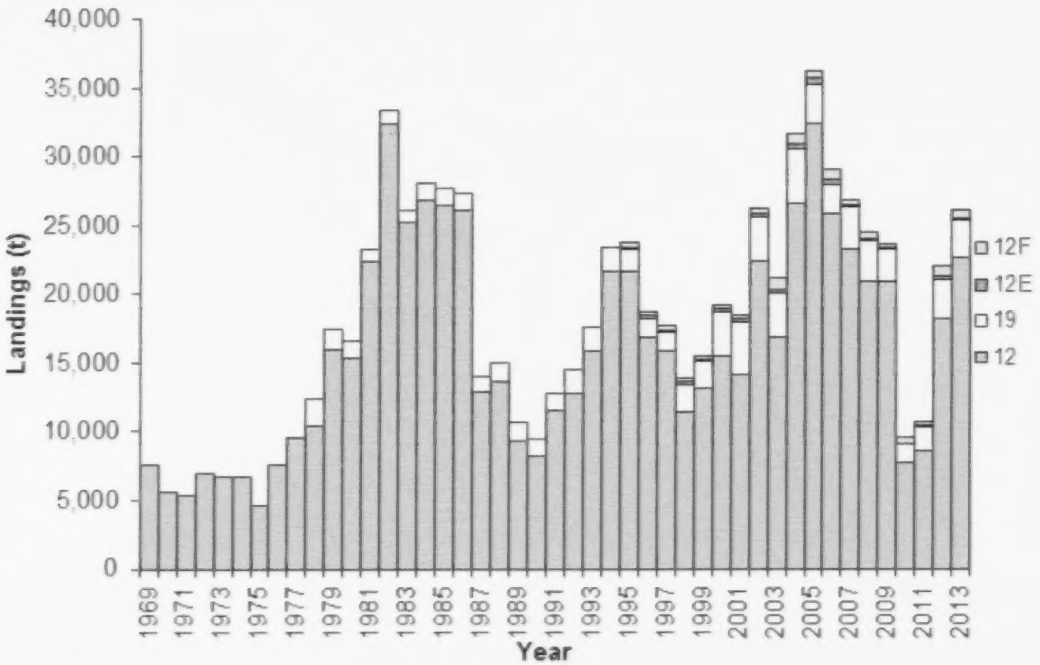

Figure 2: Landings (tons) in the southern Gulf of St. Lawrence snow crab fishery, 1969 to 2013.

The 2013 fishing season in Area 12 opened on April 28 and the last landings were recorded on July 15 with reported landings of 22,645 t (quota of 22,548 t) (Tables 1, 2; Figure 2). In accordance with the soft-shelled crab protocol, 5 of 323 grids were closed during the 2013 fishing season. The fishing effort estimated from logbooks has varied from 243,339 to 544,454 trap hauls between 1987 and 2009, but decreased considerably to 161,148 trap hauls in 2011 (Table 2), the lowest of the time series since 1987. The fishing effort was 296,398 trap hauls in 2013, an increase from 2012 (267,044 th).

Table 2. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12, 2005 to 2013.

Fishery descriptor	2005	2006	2007	2008	2009	2010	2011	2012	2013
Quota (t)	32,336	25,869	23,207	20,900	20,900	7,700	8,585	18,143	22,548
Landings (t)	32,363	25,889	23,243	20,911	20,896	7,719	8,618	18,159	22,645
CPUE (kg/trap-haul)[1]	63.7	64.4	65.7	56.4	48.2	47.9	53.0	68.0	76.4
Effort (trap hauls)	508,053	402,702	353,775	370,762	433,527	161,148	162,604	267,044	296,398
Soft-shelled crab (%) in catches[2]	3.9	3.1	2.0	3.0	5.0	6.5	6.2	3.7	2.8
Grids closed (total of 323)	68	11	5	3	78	74	233	7	5

[1] CPUE values are not standardized and do not account for changes in management measures.
[2] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

The 2013 fishing season in Area 19 opened on July 15 and the last date of landings was August 21 with reported landings of 2,657 t (quota of 2,654 t) (Tables 1, 3; Figure 2). In accordance with the white crab protocol (shell hardness <72 durometer units), no sector within Area 19 was closed during the 2013 fishing season. The fishing effort in Area 19 has varied from 16,733 to 55,977 trap hauls between 1987 and 2009, but considerably decreased to 11,138 trap hauls in 2010, the lowest of the time series since 1987. The effort in 2013 was 17,890 trap hauls.

Table 3. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 19, 2005 to 2013.

Fishery descriptor	2005	2006	2007	2008	2009	2010	2011	2012	2013
Quota (t)	2,878	2,000	3,074	3,002	2,433	1,360	1,703	2,907	2,654
Landings (t)	2,827	1,989	3,034	2,929	2,370	1,360	1,701	2,906	2,657
CPUE (kg/trap-haul)[1]	68.1	84.4	71.3	76.3	71.4	122.1	133.3	178.1	148.5
Effort (trap hauls)	41,512	23,566	42,553	38,388	33,193	11,138	12,761	16,317	17,890
White crab (%) in catches[2]	7.7	6.1	7.4	9.0	11.6	6.4	11.5	4.5	3.0
Sectors closed[3]	0/4	2/4	0/4	4/4	9/9	4/9	0/9	0/9	0/9

[1] CPUE values are not standardized and do not account for changes in management measures.
[2] The percentage is based on a durometer reading of 72. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.
[3] Total number of sectors was changed from 4 to 9 sectors in 2009.

The 2013 fishing season in Area 12E began on April 28 and the date of last landings was July 9 with reported landings of 204 t (quota of 204 t) (Tables 1, 4; Figure 2). The fishing effort in Area 12E slightly decreased from 5,623 trap hauls in 2012 to 5,097 trap hauls in 2013. In accordance

with the soft-shelled protocol, no grids within Area 12E were closed during the 2013 fishing season.

Table 4. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12E, 2005 to 2013.

Fishery descriptor	2005	2006	2007	2008	2009	2010	2011	2012	2013
Quota (t)	450	550	221	400	200	67	75	251	204
Landings (t)	449	411	220	187	67	50	76	185	204
CPUE (kg/trap-haul)[1]	80.6	40.8	37.2	20.3	14.4	27.4	31.5	32.9	40.1
Effort (trap hauls)	5,571	10,074	5,914	9,232	4,653	1,825	2,413	5,623	5,097
Soft-shelled crab (%) in catches[2]	2.9	7.8	1.3	10.1	7.8	14.7	8.4	3.3	15.9
Grids closed (total of 8)	0	2	0	0	2	0	0	0	0

[1] CPUE values are not standardized and do not account for changes in management measures.
[2] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

In Area 12F, the fishery in 2013 opened on April 24 and the last date of recorded landings was June 26 with reported landings of 543 t (quota of 543 t) (Tables 1, 5; Figure 2). The fishing effort decreased from 16,890 trap hauls in 2012 to 11,086 trap hauls in 2013. In accordance with the soft-shelled protocol, no sector within Area 12F was closed during the 2013 fishing season.

Table 5. Quota and landings (t), fishing effort (trap hauls) and catch performance for the snow crab fishery in Area 12F, 2005 to 2013.

Fishery descriptor	2005	2006	2007	2008	2009	2010	2011	2012	2013
Quota (t)	480	815	408	585	465	420	314	706	543
Landings (t)	479	787	370	431	309	420	313	706	543
CPUE (kg/trap-haul)[1]	93.7	55.9	30.2	27.8	22.0	29.3	32.5	41.8	49.0
Effort (trap hauls)	5,112	14,079	12,252	15,504	14,045	14,335	9,631	16,890	11,086
Soft-shelled crab (%) in catches[2]	0.8	3.5	2.4	7.3	11.4	8.6	2.6	9.4	2.4
Sectors closed (total of 3)	0	0	1	3	3	2	0	0	0

[1] CPUE values are not standardized and do not account for changes in management measures.
[2] The percentage is based on a durometer reading of 68. Catches are defined as male crab of all sizes (commercial >= 95 mm and non-commercial) in traps.

Catch per unit of effort (CPUE) expressed as kg per trap-haul (kg/th) is calculated directly from logbook data as the ratio of total landings (kg) to total effort (trap-hauls). CPUE values are not standardized and do not account for changes in management measures and fishing practices and as a result may not be directly proportional to biomass. In Area 12, the annual mean CPUE increased in 2013 (76.4 kg/th) compared to 2012 (Table 2; Figure 3). In Area 19, the CPUE has been increasing since 2009 and reached 178.1 kg/th in 2012, but decreased to 148.5 kg/th in 2013 (Table 3, Figure 3). The CPUE in Areas 12E (40.1 kg/th) and 12F (49.0 kg/th) increased in 2013 compared to 2012 (Tables 4, 5; Figure 3). Catch per unit of effort (CPUE) estimated from at-sea observer sampling of individual traps provides generally similar trends in CPUE to those estimated from logbooks.

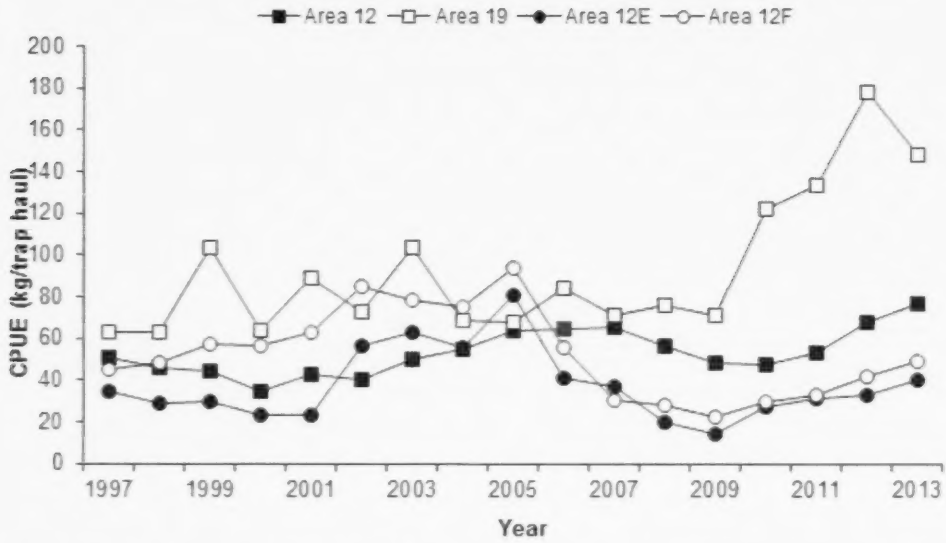

Figure 3: Catch per unit effort (kg per trap haul) in the southern Gulf of St. Lawrence snow crab fishery, Areas 12, 19, 12E and 12F, based on logbooks, 1997 to 2013.

The percentage of soft-shelled crab and white crab is calculated using data collected from the at-sea observer program. The incidence of soft-shelled crab and white crab in catches is strongly influenced by the fishing strategy used by harvesters during the season, as well as commercial-sized adult crab abundance in the area.

The percentage of soft-shelled crab in Area 12 in 2013 was 2.8%, a decrease from 2012, and has remained low since 2004 (Table 2). In Area 19, the percentage of white crab was 3.0% in 2013, a decrease from 2012, and the lowest since 2005 (Table 3). The percentage of soft-shelled crabs in Area 12E in 2013 was 15.9%, a large increase from 2012 and the highest values since 2005 (Table 4). In Area 12F, the percentage of soft-shelled crabs in 2013 was 2.4%, a decrease from 2012, and tie for the second lowest value in the 2005 to 2012 period (Table 5).

ASSESSMENT

Snow crab in fishing areas 12, 19, 12E, and 12F comprise a single biological population and the southern Gulf of St. Lawrence stock is considered as one unit for assessment purposes.

The survey design and biomass estimation polygon covers the entire area of the southern Gulf of St. Lawrence defined by the 20 to 200 fathoms depth contours (corresponding to the areal extent of bottom temperatures < 5 °C which are favourable for snow crab and encompassing the area of the southern Gulf of St. Lawrence biological unit) (Figure 4). The sampling design was modified in 2013 from 2012 with an increase in the number of stations in 2013 to 355 from 325 in 2012 (DFO 2013; Hebert et al. 2014). The survey spatial sampling design partitioned this area into square grids of 12.7 km x 12.7 km. The increase in the number of stations in 2013 was the result of a request from the snow crab advisory committee to increase the number of sampling stations in the smaller fishing zones. A total of 444 tows were attempted in 2013 and 352 stations were successfully trawled; three sampling squares had to be abandoned due to

failures to successfully trawl the area. The survey was conducted between July 9 and Oct. 14, 2013. All at-sea survey and sampling protocols were identical to previous years.

There was a vessel change in 2013 and trawl mensuration equipment from a different manufacturer was used compared to previous years. The survey in 2013 was financed through a collaborative agreement with the fishing industry under Section 10 of the Fisheries Act.

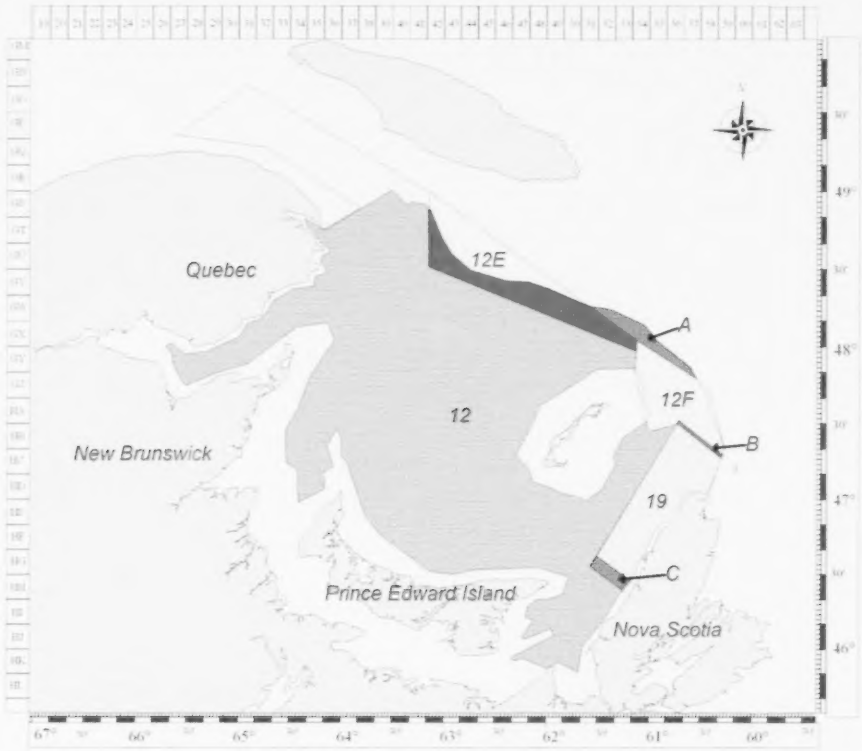

Figure 4: The survey and estimation polygon of 57,840 km^2 used for the 2013 snow crab (Chionoecetes opilio) stock assessment in the southern Gulf of St. Lawrence (all of the coloured areas) and corresponding estimation polygons for the four crab fishing areas (12, 12E, 12F, and 19). The unassigned zone north of areas 12E and 12F (label A) and buffer zones (labels B and C) are also shown.

Stock Trends and Current Status in the Southern Gulf

Interpretation of stock status is based on inferences from abundance data from annual trawl surveys conducted during July to October, over the entire area of snow crab distribution in the southern Gulf. The surveys provide estimates of commercial biomass which are comprised of residual biomass (hard-shelled adult males of legal size remaining after the fishery) and recruitment biomass (soft-shelled adult males >= 95 mm CW (R-1) that will be available to the fishery the following fishing season). The snow crab trawl survey also provides indices of future male recruitment to the fishery (pre-recruits defined as R-4, R-3 and R-2). The pre-recruits R-4, R-3 and R-2 represent adolescent male crabs with a carapace width range of 56-68, 69-83, and larger than 83 mm, respectively. A portion of these crabs could be available to the fishery in 4, 3 and 2 years, respectively. An index of abundance of small male crab (34-44 mm CW) is also presented as an indicator of potential long-term recruitment. It takes at least six years for these small male crabs to reach the commercial size of 95 mm CW.

Spawning stock abundance consists of females (pubescent and mature). The term pubescent refers to females that will molt to maturity and mate the following year and become primiparous females (first brood). The term 'multiparous' refers to females which are carrying a brood for the second time or more. The term 'mature females', includes primiparous and multiparous females.

The biomass of commercial-sized adult males in the southern Gulf of St. Lawrence from the 2013 trawl survey was estimated at 65,868 t (95% confidence interval (C.I.) range of 56,283 t to 76,610 t; Table 6; Figure 5). The estimated commercial biomass in the southern Gulf decreased by 12.2% relative to the 2012 estimate (74,997 t; 95% C.I. 65,822 t – 85,086 t).

The recruitment to the fishery at the time of the 2013 survey was 38,981 t (95% C.I. 28,969 t to 51,346 t), comprising 59.2% of the commercial biomass (Table 6; Figure 5). The recruitment to the fishery in 2013 decreased by 20.4% compared to the 2012 estimate. The residual biomass (carapace conditions 3 to 5) of commercial-sized adult male crab after the 2013 fishery was estimated at 26,886 t (95% C.I. 22,909 t to 31,352 t), which is comparable to 2012 (Table 6; Figure 5).

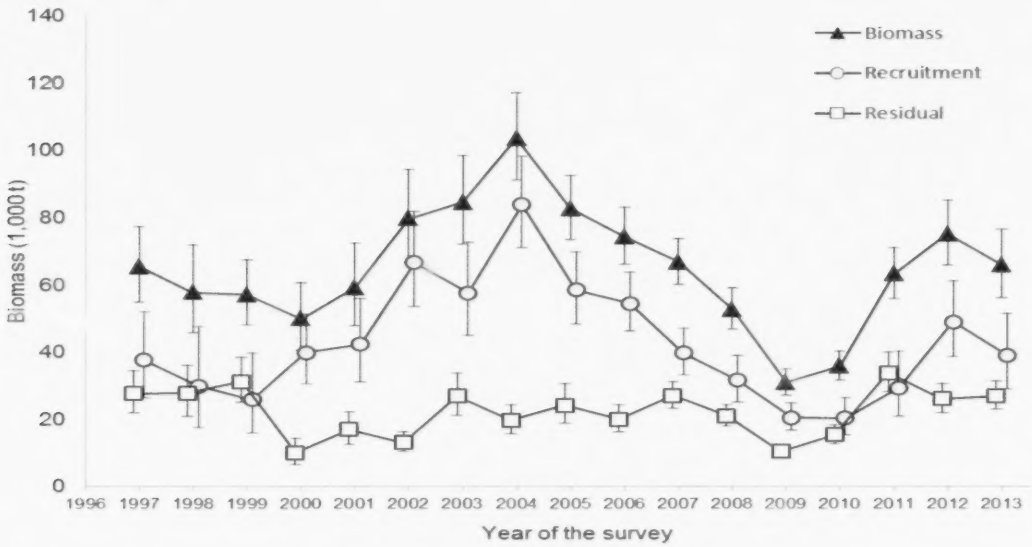

Figure 5: Total commercial biomass, recruitment commercial biomass, and residual commercial biomass (1,000 t; means with 95% confidence intervals) in the southern Gulf of St. Lawrence, 1997 to 2013.

A second fishery independent survey of the southern Gulf of St. Lawrence is used to provide an index of biomass of commercial-sized adult male crab. The multi-species research vessel bottom trawl survey, a stratified random design, has been conducted annually in September since the early 1970's although the estimation of commercial-sized adult male crab biomass is available only since 2001.

Over the available time series, the September multi-species bottom trawl survey index shows generally similar trends in biomass (within the estimation precisions of the surveys) in commercial adult male snow crab biomass between 2001 and 2013 as the biomass estimates from the dedicated snow crab trawl survey (Figure 6).

Table 6. Total commercial, recruitment, and residual biomass (t; means with 95 % confidence intervals) of commercial-sized adult male crabs (>= 95 mm carapace width) in the southern Gulf of St. Lawrence, 1997 to 2013.

Year of the survey	Commercial Biomass	Recruitment Biomass	Residual Biomass
1997	**65,310** 54,801-77,239	**37,619** 26,376-52,064	**27,690** 21,995-34,407
1998	**57,595** 45,630-71,735	**29,818** 17,580-47,435	**27,775** 21,022-36,013
1999	**57,051** 47,946-67,376	**25,874** 15,918-39,818	**31,177** 25,051-38,346
2000	**49,823** 40,473-60,682	**39,845** 30,543-51,093	**9,977** 6,649-14,401
2001	**59,150** 47,740-72,460	**42,243** 31,198-55,942	**16,905** 12,657-22,125
2002	**79,559** 66,688-94,181	**66,481** 53,434-81,746	**13,075** 10,451-16,157
2003	**84,423** 71,964-98,410	**57,503** 44,809-72,679	**26,919** 21,223-33,674
2004	**103,429** 91,029-117,036	**83,702** 70,955-98,069	**19,726** 15,836-24,280
2005	**82,537** 73,487-92,387	**58,398** 48,417-69,824	**24,140** 18,726-30,632
2006	**74,285** 66,192-83,087	**54,371** 46,124-63,660	**19,914** 16,161-24,275
2007	**66,660** 60,183-73,638	**39,635** 33,089-47,092	**27,025** 23,354-31,106
2008	**52,564** 46,658-59,006	**31,555** 25,181-39,048	**21,010** 17,960-24,426
2009	**30,920** 27,237-34,959	**20,520** 16,848-24,754	**10,399** 8,560-12,516
2010	**35,795** 31,681-40,291	**20,351** 15,360-26,450	**15,444** 12,859- 18,394
2011	**63,162** 55,965-71,022	**29,394** 20,909-40,190	**33,768** 28,297-39,985
2012	**74,997** 65,822-85,086	**48,969** 38,667-61,173	**26,028** 21,950-30,641
2013	**65,868** 56,283-76,610	**38,981** 28,969-51,346	**26,886** 22,909-31,352

In the 2013 trawl survey, geographic concentrations of commercial-sized adult males were located in Bradelle Bank, in Chaleur Bay, the southern part of the Magdalen Channel and notably in the west of Cape Breton Island (Figure 7). The spatial distributions of commercial-sized adult males have varied annually during increasing and decreasing phases of the commercial biomass (Figure 8).

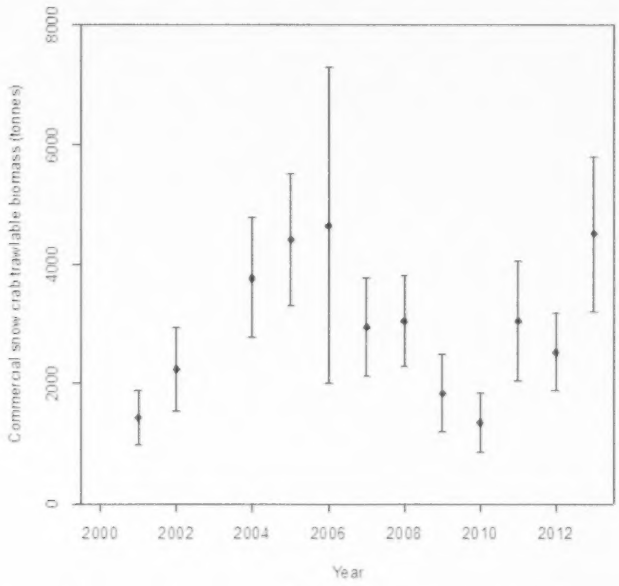

Figure 6: Index of trawlable biomass (t, means and 95% confidence intervals) of adult male snow crab ≥95 mm carapace width in the September RV survey for 2001 to 2013 excluding 2003. Series are presented for CCGS Teleost vessel catches based on a geographic area comparable to that used for the current snow crab assessment.

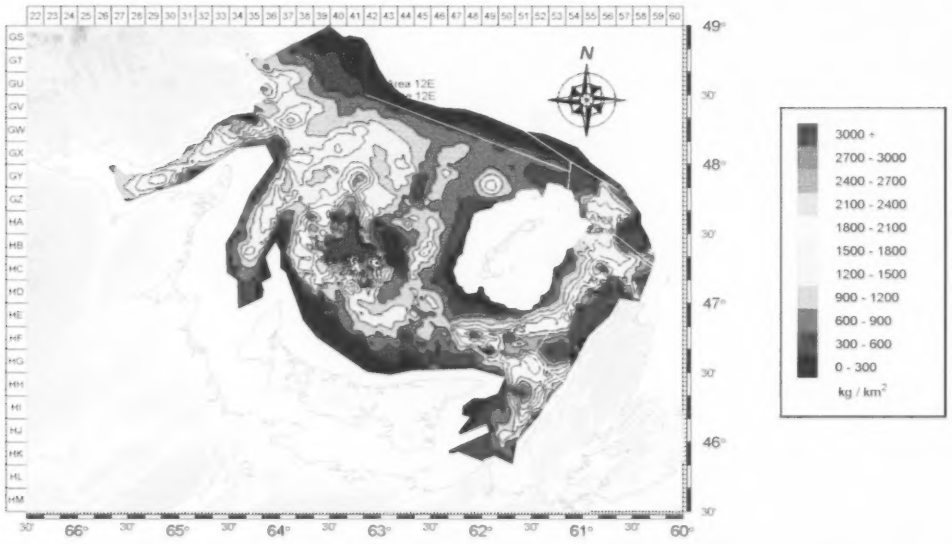

Figure 7: Density (kg per km^2) contours of commercial-sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence in 2013.

Figure 8: Density (kg per km^2) contours of commercial-sized adult male crab (≥95 mm CW) in the southern Gulf of St. Lawrence, 2004 to 2012.

As requested by DFO Fisheries and Aquaculture Management, the 2013 commercial biomass estimates in snow crab fishing areas (12, 19, 12E and 12F), two buffer zones (between areas 12F and 19, between areas 12 and 19) and the unassigned zone (north of areas 12E and 12F), as shown in Figure 4, are summarized in Table 7. The majority of biomass was found in Area 12, followed by Area 19, 12F, 12E, buffer zones, and the unassigned zone (Table 7).

The exploitation rate in the southern Gulf of St. Lawrence is calculated as the ratio between the catch of the fishery in the year of the assessment and the commercial biomass estimated from the trawl survey in the previous year. In 2013, the exploitation was 34.7%. The exploitation rates varied between 21% and 45% from 1998 to 2011 (Figure 9).

Total mortality is calculated as residual biomass estimated from the survey in the year of the assessment divided by the biomass available to the fishery as estimated in the previous year's survey. In 2013, total mortality was estimated at 64.2% (Figure 9). The total mortality has varied between 45.8% and 82.5% since 1997, except for 2011 when it was estimated at 5.6% (Figure 9).

Table 7. Estimates of commercial biomass (t; means and 95% confidence intervals) in 2013 for the southern Gulf of St. Lawrence estimation polygon of 57,840 km^2 and for each of the snow crab fishing areas 12, 19, 12E, 12F, the buffer zones, and the unassigned zone. Labels refer to those in Figure 4.

Areas	Surface area (km^2)	Commercial biomass (t)	
		Mean	95% confidence intervals
Southern Gulf [1]	57,840	65,868	56,283 - 76,610
Area 12	48,028	50,867	42,594 – 60,273
Area 19	3,833	9,795	8,175 – 11,690
Area 12E	2,443	409	19 – 2,083
Area 12F	2,438	4,064	2,793 – 5,718
Subtotal of crab fishing areas	56,742	65,135	
Unassigned zone above 12E and 12F (label A)	674	81	0 – 540
Buffer zone 19 / 12F (label B)	112	299	187 - 454
Buffer zone 12 / 19(label C)	310	483	190 - 1,018
Total of all individual area estimates [1]	57,838	65,998	

[1] Small differences in the sum of all individual area estimates compared to the southern Gulf estimates are due to rounding of intermediate calculation precisions

Over the time series, the estimated commercial biomass from the survey was 29.6% higher than the sum of the residual biomass and the landings of the following year. This difference (termed non-fishing directed mortality) could be attributed to a number of factors including misattribution of recruitment and residual groups, variability in survey estimates, natural mortality, non-directed fishery induced mortalities, as well as crab movement in and out of the sampling area.

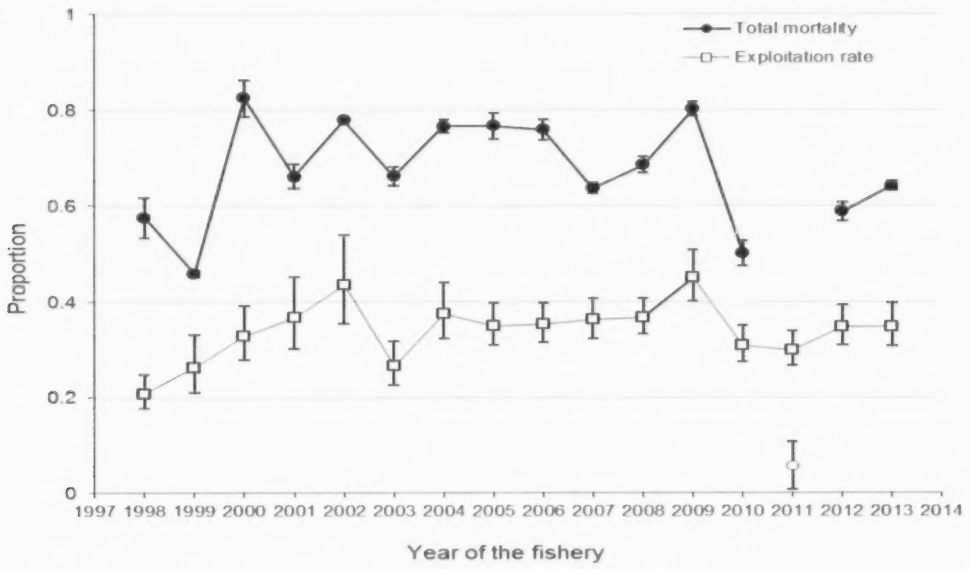

Figure 9: Exploitation rates (± 95% confidence intervals) by the fishery and total mortality of commercial-sized adult male snow crab in the southern Gulf of St. Lawrence, 1997 to 2013. The 2011 total mortality point is isolated from the series due to uncertainties (see Sources of Uncertainty).

Based on abundances of adolescent males of R-2, R-3 and R-4 from recent surveys, the predicted recruitment of commercial-sized adult male crab for the 2015 fishery was estimated at 37,893 t (95% C.I. 28,568 to 49,114 t) (Figures 10 and 11). The index of abundance of small male crab (34-44 mm CW) from the trawl survey in 2013 decrease compared to the index estimated in 2012 (Figure 12).

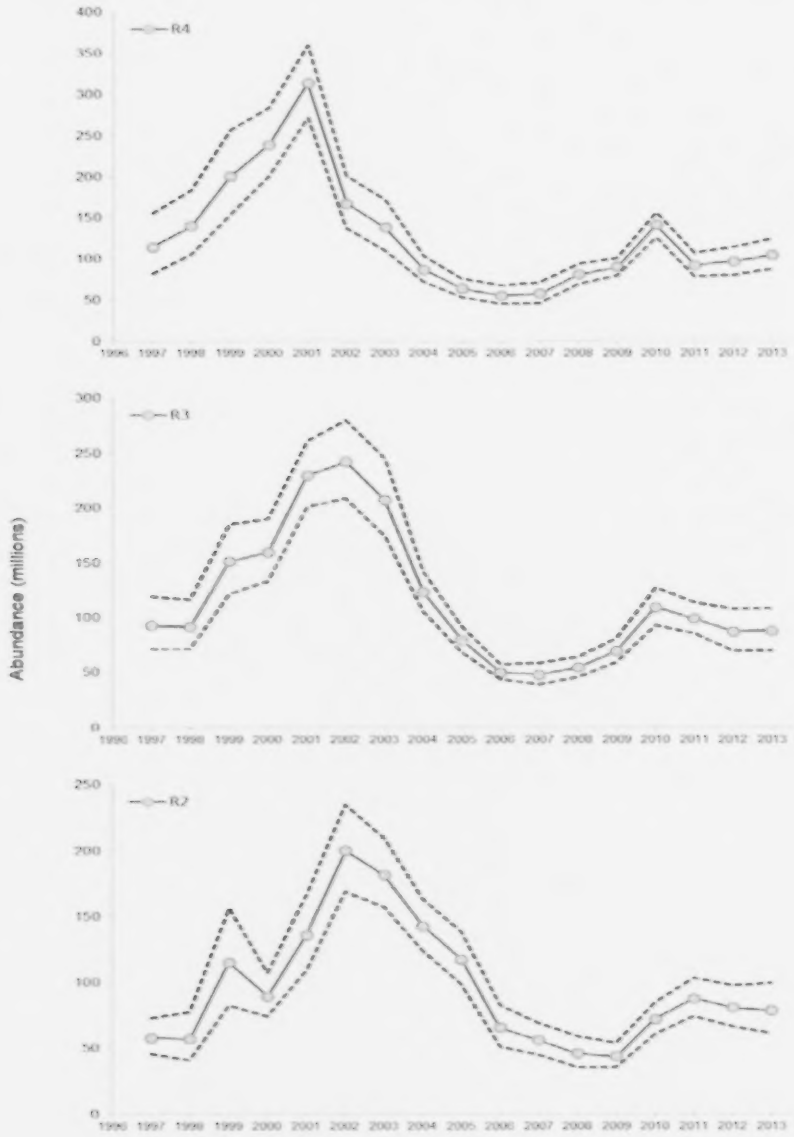

Figure 10: Estimated abundances (millions; means and 95% confidence intervals) of R-4 (upper panel), R-3 (middle panel) and R-2 (lower panel) adolescent male crabs in the southern Gulf of St. Lawrence for the survey years 1997 to 2013.

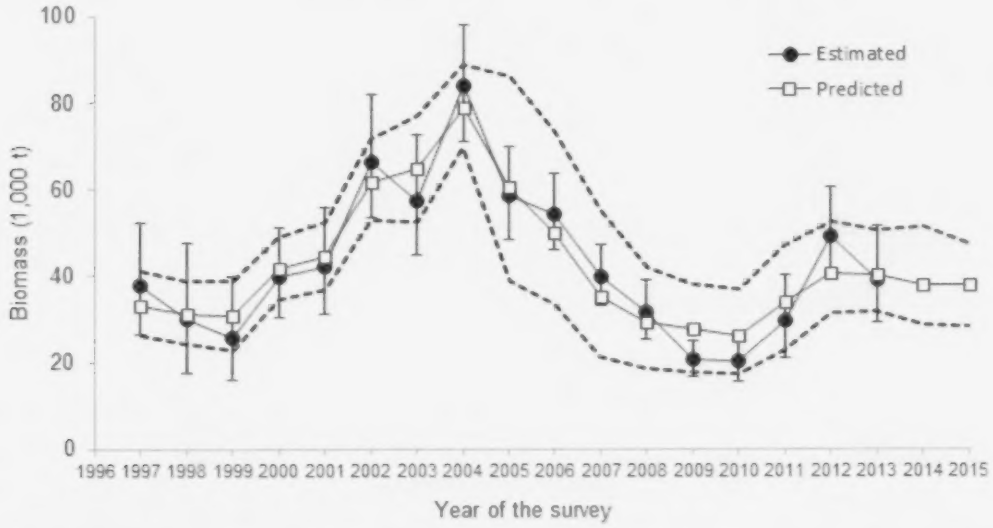

Figure 11: Estimated (black circle symbols are the means with 95% confidence interval vertical bars) and predicted (open square symbols are the means with the 95% confidence interval bands as dashed lines) biomasses of R-1 (adult male crabs >= 95 mm carapace width of carapace condition 1 and 2) snow crab in the year of the survey, 1997 to 2015. The predicted abundances are based on a relationship to the estimated abundances of R-2 (adolescent male crab larger than 83 mm CW) in the previous year. Predictions of R-1 biomasses for 2014 and 2015 are based on abundances of R-2, R-3, and R-4 estimated in 2013 and shown in Figure 10.

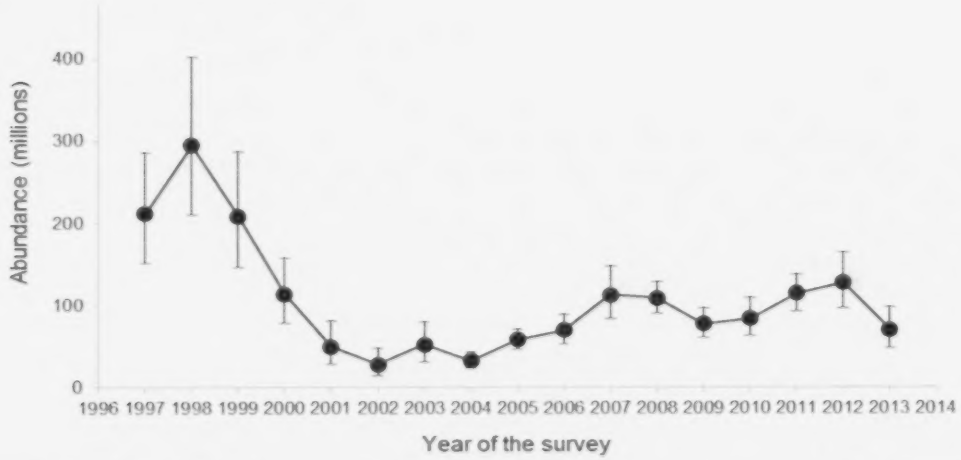

Figure 12: Index of abundance (means with 95% confidence intervals, numbers in millions,) of small male crab of 34 to 44 mm CW, based on the trawl surveys conducted in the southern Gulf of St. Lawrence, 1997 to 2013.

Reproduction

The abundance of mature females decreased in 2013 compared to 2012 and was lower than the historical average (1997-2012), (Figure 13). The decrease of pubescent females observed in the 2013 survey suggests that the abundance of mature females may decrease in the coming years (Figure 13).

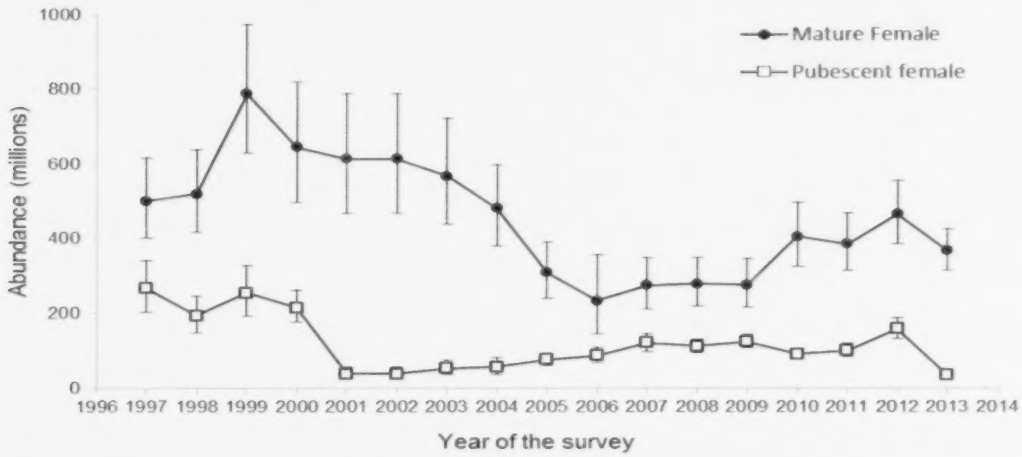

Figure 13: Estimated abundances (millions; means and 95% confidence intervals) of mature female (grey circle symbols) and pubescent females (open square symbols) in the southern Gulf of St. Lawrence based on the trawl surveys during 1997 to 2013.

Sources of Uncertainty

A Snow Crab Assessment Methods Framework Science Review was conducted in November 2011 to address concerns about the variations in survey design and sample coverage, the standardization of area swept, and the area of the estimation polygon to be used (DFO 2012a). Following the review, it was agreed that the biomass time series from 1997 to the present was a coherent time series to be used in assessing stock status and providing catch advice. Further work was required to determine if the earlier part of the time series between 1989 and 1996 for which survey coverage was much less than the coverage from 1997 to the present, could also be used to assess snow crab abundance in the southern Gulf of St. Lawrence. This work has begun.

The estimate of residual biomass in 2011 was abnormally high relative to the expected value from the 2010 survey and the fishery in 2011. This discrepancy may be due to a number of factors including misattribution of recruitment to the residual crab category in 2011. It was noted that the abundance of skip molters in the eastern portion of the southern Gulf of St. Lawrence was high in 2010. These crabs would have molted much earlier (four months) than normal molters (Hebert et al. 2012). Due to the earlier molt, these crabs become harder with some epibionts on the carapace sooner in the following year than normal molters. This could become a serious issue when the survey period is prolonged towards late fall. Another possibility is the underestimation of commercial biomass in 2009 and 2010 and / or overestimation of biomass in 2011, which could be verified using a secondary fishery independent survey such as the September multi-species survey. Other factors such as the movement of unaccounted amount of crab from outside the southern Gulf of St. Lawrence biological unit cannot be ignored.

There have been changes in survey vessel over the 1997 to 2013 assessment period, including a change in vessel in 2013 from the vessel which had been used during 2003 to 2012. There have never been any comparative experiments to assess if there were changes in catchability between vessels. Changes in survey catch rates over time may not accurately reflect changes in stock size if survey vessels have different catchabilities.

There were 66 successful tows in 2013 for which there were incomplete useable trawl mensuration data with which to estimate the swept area of the tow. The proportion of stations

for which useable trawl mensuration data was not available was similar to other years. There was a change in trawl mensuration equipment in 2013 which was not expected to have resulted in less reliable information. Additional sensors which would result in a more reliable platform for collecting these data could resolve some of the data gaps in mensuration data collection.

Procedures for estimating the swept area in the cases of missing trawl measurement data should be reviewed to ensure that the mean values used are appropriate. The review of the consequences of this adjustment procedure would need to be conducted for all the years.

The unstandardized catch per unit effort from the fishery correlates weakly with the estimated biomass from the assessment. This results in differences in perception of stock abundance from the fishing industry observations (CPUE and changes within the season) from those of the assessment. A spatially and temporally designed analysis of the CPUE data and densities of crab from the survey could provide clarification of this divergence.

The proportion of the estimated abundance of commercial sized adult male crab in Area 19 to the southern Gulf has increased in recent years. The causes of the increased proportion of crab in this zone are not known; migration from within or outside of the southern Gulf and changes in the environment as factors may be at play.

Temperature in the southern Gulf varies annually. In recent years, the temperatures have been above normal and the index of suitable habitat for crab has declined. These changes in temperature can affect a number of life history processes including molting and growth, reproduction, and larval development. The impacts of warming conditions on the snow crab life history are not well understood.

CONCLUSIONS AND ADVICE

Within the Precautionary Approach (PA) framework (DFO 2009), the Limit Reference Point for biomass (B_{lim}) defines the critical / cautious zones and an upper stock reference (B_{USR}) delimits the cautious / healthy zones on the stock status axis. A removal rate limit reference point (F_{lim}) defines the maximum removal rate in the healthy zone. The upper stock reference point (B_{USR}) is 41,400 t of commercial-sized adult males of all carapace conditions as estimated from the trawl survey (DFO 2012b). Commercial-sized adult male crabs of all carapace conditions are available for the fishery in the year following the trawl survey. The biomass limit reference point (B_{lim}) value is 10,000 t (DFO 2012b). The biomass limit reference point was chosen as the lowest biomass of hard shelled commercial-sized adult males which produced good recruitment rates of small male crabs of 34-44 mm CW (referred to as Instar VIII) (DFO 2010). The removal reference point (F_{lim}) is 34.6% (DFO 2012b). The southern Gulf of St Lawrence commercial biomass estimate from the trawl survey should be used for evaluating catch options relative to the defined reference points.

The trajectory of stock abundance (biomass of commercial-sized adult male crab from the snow crab trawl survey in year t - 1) versus exploitation rate on this biomass in the fishery of year t is shown in Figure 14. The commercial biomass has varied between 30,920 t and 103,429 t during 1998 to 2013. Over this same period, exploitation rates have varied between 20.8% and 45.0%. The estimated biomass from the 2013 snow crab survey, which would be available to the fishery in 2014, is 65,868 t (95% CI 56,283 – 76,610 t). The 2013 survey biomass estimate is in the healthy zone.

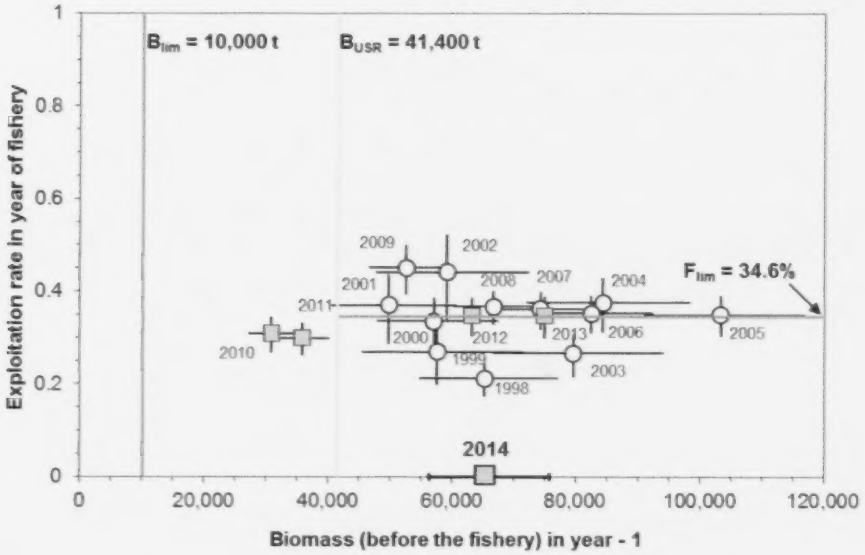

Figure 14: Trajectory of stock abundance (biomass of commercial-sized adult male crab as estimated from the trawl survey in year before the fishery) versus exploitation rate in the fishery year. Year of the fishery is labeled on the figure. Error bars are 95% confidence intervals. White circle symbols are biomass and exploitation rate levels used to define the reference points. The grey squares are the years when the reference points were used within the PA to decide on the fishery quota. The biomass estimate available for the 2014 fishery (with 95% confidence interval) is also shown.

A risk analysis was developed relative to various catch options in 2014 (Table 8; Figure 15). Candidate decision rules that conform to the Precautionary Approach framework have been evaluated and a number of rules were evaluated as conforming to the Precautionary Approach (DFO 2014). The choice of a decision rule has not been finalized but it is expected that a rule will be established in the future and used to determine the annual TAC.

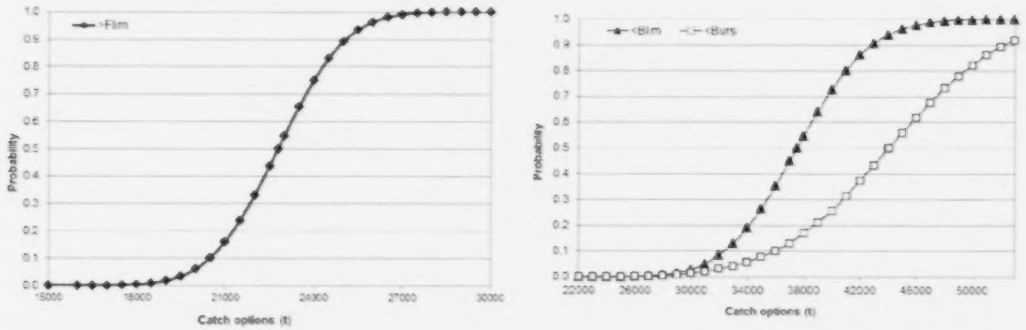

Figure 15: Risk analysis of catch options in 2014 for the southern Gulf of St. Lawrence snow crab fishery. Left panel shows the probabilities of exceeding F_{lim}. The right panel shows probabilities of the hard-shell commercial-sized adult male biomass in 2014 falling below B_{lim} (black triangles) and of the commercial-sized adult male biomass in 2014 being below B_{USR} (open squares) after the 2014 fishing season.

Table 8. Risk analysis of catch options in 2014 for the southern Gulf of St. Lawrence snow crab fishery showing probabilities of exceeding F_{lim}, of the hard-shell commercial-sized adult male remaining biomass falling below B_{lim}, and of the total commercial-sized adult male biomass being below B_{USR} post-fishery in 2014. Also shown is the expected commercial biomass for the 2015 fishery.

	Probability			
Catch option (t)	> F_{lim} (0.346)	< B_{lim} (10,000 t)	< B_{USR} (41,400 t)	Expected biomass for the 2015 fishery
15,000	0	0	0	70,450 (59,888-80,943)
16,000	< 0.01	0	0	69,450 (58,888-79,943)
17,000	< 0.01	0	0	68,450 (57,888-78,943)
18,000	<0.01	0	0	67,450 (56,888-77,943)
19,000	0.02	0	0	66,450 (55,888-76,943)
20,000	0.06	0	0	65,450 (54,888-75,943)
21,000	0.16	0	0	64,450 (53,888-74,943)
22,000	0.33	0	< 0.01	63,450 (52,888-73,943)
22,790	0.50	< 0.01	< 0.01	62,660 (52,098-73,153)
23,000	0.55	< 0.01	< 0.01	62,450 (51,888-72,943)
24,000	0.75	< 0.01	< 0.01	61,450 (50,888-71,943)
25,000	0.89	< 0.01	< 0.01	60,450 (49,888-70,943)
26,000	0.96	< 0.01	< 0.01	59,450 (48,888-69,943)
27,000	0.99	< 0.01	< 0.01	58,450 (47,888-68,943)
28,000	>0.99	0.01	0.01	57,450 (46,888-67,943)
29,000	> 0.99	0.02	0.01	56,450 (45,888-66,943)
30,000	1	0.03	0.01	55,450 (44,888-65,943)
37,510	1	0.50	0.15	47,940 (37,550-58,586)
43,970	1	0.94	0.50	43,970 (31,090-52,120)

OTHER CONSIDERATIONS

Environmental Considerations

In 2013, near-bottom temperatures were normal in the southern portion of area 12 and above normal in its northern portion as well as in Areas 12E and 12F. Temperatures in Area 19 were around normal except along the very-near coast where they were slightly lower than normal values. Most of the snow crab fishing grounds cooled down in 2013 compared to 2012, except for the Shediac Valley area where the water slightly warmed up. The warmer-than-average bottom waters of 2013 resulted in a below normal Southern Gulf snow crab habitat index (bottom area with temperatures from -1 to 3°C; Figure 16). In 2013, the habitat index was similar to 2012 and was 3.7% below the 1980-2010 average. The mean temperature (1.0°C) within the defined snow crab habitat area index (-1 to 3°C) in 2013 decreased compared to 2012 by about 0.4°C (Figure 16). During the previous year (2012), the mean temperature was the highest of the 42 year data series and the 2013 value is still significantly higher than the long term mean and is above the 1999-2002 and 2005-2007 warm periods. The mean temperature has been above normal over the last five years and for 12 of the last 15 years.

Snow crab is a stenothermic species with a preference for colder water temperatures. A temperature regime shift from cold to warm may have impacts on population dynamics of snow crab such as shortened reproductive cycles, increased per capita fecundity, and increased size at maturity, greater natural mortality, spatial contraction of habitat, and skewed sex ratio for reproduction. The stock may be more vulnerable to commercial fishing pressure under climate-driven changes resulting in increasing temperatures. Furthermore, the outcome of climate

change on snow crab population dynamics can be relatively abrupt and even detrimental, and the direction of the effect may be difficult to predict (Sainte-Marie et al. 2008).

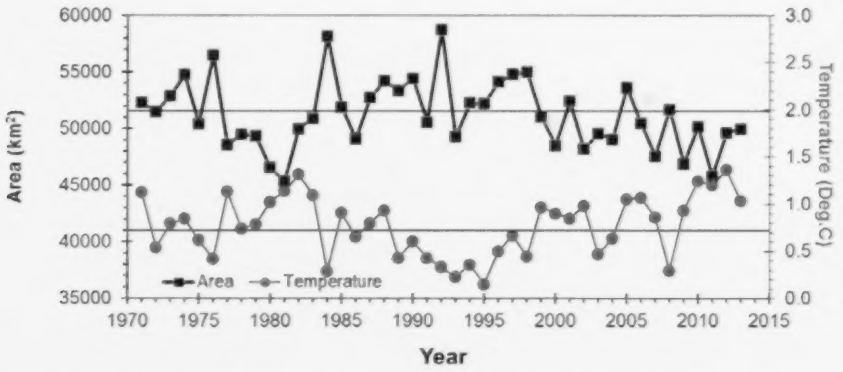

Figure 16: Snow crab temperature habitat area index (km²) that encompasses water temperatures of -1 to 3 °C (upper panel) and the mean temperature (°C) within the temperature area index (lower panel) in the southern Gulf of St. Lawrence, 1971 to 2013.

Sampling considerations

The redesign of the sampling grid in 2013 and random assignment of stations in each square resulted in an important number of rejected tows due to trawling over rough bottom and gear damage. A total of 444 tows were conducted to realize the 352 successful tows. There is a higher probability of gear damage and failed tows when stations are randomly assigned and sampled, rather than using fixed stations known to be conducive to successful trawling within individual grid squares. Use of fixed stations in subsequent years is a reasonable approach to optimize data collection efforts.

SOURCES OF INFORMATION

This Science Advisory Report is from the Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, regional advisory meeting of January 29-31, 2014 on the assessment of the status of the southern Gulf of St. Lawrence snow crab stock. Additional publications from this process will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

DFO. 2006. Proceedings of the Assessment Framework Workshop on the southern Gulf of St. Lawrence snow crab (Areas 12, E, F and 19), Gulf Regional Advisory Process; 11-14 October 2005. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2006/042.

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

DFO. 2010. Reference points consistent with the precautionary approach for snow crab in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/014.

DFO 2012a. Proceedings of the Gulf Region Science Peer Review Framework Meeting of Assessment Methods for the Snow Crab Stock of the southern Gulf of St. Lawrence; November 21 to 25, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2012/023.

DFO. 2012b. Revised reference points for snow crab to account for the change in estimation area of the southern Gulf of St. Lawrence biological unit. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/002.

DFO. 2013. Assessment of snow crab in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F) and advice for the 2013 fishery. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2013/002.

DFO. 2014. Assessment of candidate harvest decision rules for compliance to the Precautionary Approach framework for the snow crab fishery in the southern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2014/007.

Hébert, M., Wade, E., Biron, M., DeGrâce, P., Landry, J.-F., and Moriyasu, M. 2012. The 2011 assessment of the snow crab (*Chionoecetes opilio*) stock in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). DFO Can. Sci. Advis. Sec. Res. Doc. 2012/080.

Hébert, M., Wade, E., DeGrâce, P., Landry, J.-F., and Moriyasu, M. 2014. The 2012 assessment of the snow crab (*Chionoecetes opilio*) stock in the southern Gulf of St. Lawrence (Areas 12, 19, 12E and 12F). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/111.

Moriyasu, M., Wade, E., Hébert, M., and Biron, M. 2008. Review of the survey and analytical protocols used for estimating abundance indices of southern Gulf of St. Lawrence snow crab from 1988 to 2006. DFO Can. Sci. Advis. Sec. Res. Doc. 2008/069.

Sainte-Marie, B., Gosselin, T., Sévigny, J.-M., and Urbani, N. 2008. The snow crab mating system : opportunity for natural and unnatural selection in a changing environment. Bulletin of Marine Science 83: 131-161.

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